ON

MICROMETERS APPLIED TO MICROSCOPES.

BY

WILLIAM ROBERTSON, M.D., F.R.C.P.,
EDINBURGH.

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The ordinary stage-micrometer, as constructed by the best English and foreign opticians, cannot be directly applied to the measurement of very minute objects. Although it can be procured at a moderate price, and with divisions beautifully ruled on glass at intervals of $\frac{1}{100}$th of a millimetre apart, the scale is far too coarse for the use of the histologist; and it is usually quite impossible, in examining certain objects under high magnifying powers, to bring their edges into proper focus while the ruled lines of the scale continue tolerably defined.

The eyepiece-micrometer, consisting of a scale ruled on glass, and inserted in the stop or diaphragm of the ordinary negative eyepiece, is a very convenient instrument, enabling the observer, when using a magnifying power of 500 or 600 diameters, to estimate spaces of about $\frac{1}{200}$th or $\frac{1}{300}$th of a millimetre with tolerable precision, in favourable circumstances. But the breadth of the lines on the best ruled eyepiece-scale is so considerable, and the shadows caused by their channels so perplexing, even when the illumination is carefully managed, that, where extreme accuracy is required, other apparatus must be employed.

The cobweb screw-micrometer, when well constructed, is a far more perfect instrument; but, as Mr Quekett remarks,[1] "the measurements made by it are by no means so delicate as they appear to be." In taking a unit, from which to construct the scale, a stage micrometer must be employed, and on the accuracy with which this is graduated depends, of course, the exactness of the subdivisions effected by means of the screw. This objection applies equally to all eyepiece-micrometers; but the screw-instrument has the positive disadvantages of being constructed of parts very apt to become deranged,

[1] Practical Treatise on the Use of the Microscope, p. 196.

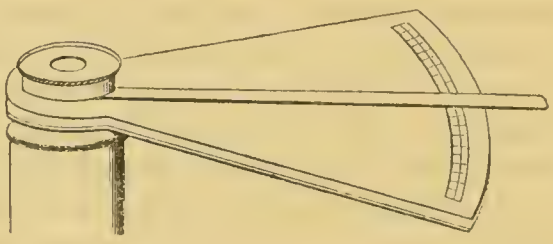
and capable of being replaced by none but a first-rate workman. The effects of friction cannot be wholly obviated; the screw is apt to wear, and to wear unequally; and the uniformity of all its parts,—even when it leaves the workman's hands,—may be reasonably suspected. The price is necessarily so high as to preclude its general employment by those engaged in microscopic observations.

Welcker's Micrometer.—In Henle and Pfeufer's "Zeitschrift für Rationelle Medicin" (band X. heft 1), Hermann Welcker, a medical student at Giessen, proposes a new kind of micrometer, capable of furnishing indications of extreme delicacy, and in elegance of principle and cheapness far surpassing the cobweb screw-micrometer.

The following description will enable any one familiar with the elementary principles of trigonometry to comprehend the mode of constructing and using such an instrument:—

Construction.—Across the stop of an ordinary negative eyepiece, two very fine threads, from a small spider cocoon, are stretched at right angles to each other, and, by means of a little copal varnish, are fixed in such a position that the shorter intersects the longer thread, cutting off about one quarter of its length. The relative position of the threads is shown in Figs. II. and III., where they are indicated by the letters A B and C D. To the upper part of the tube of the microscope is fixed transversely a brass plate, along which plays a pointer, firmly attached to the eyepiece immediately beneath its milled rim. The appearance of this apparatus is shown on a reduced scale in Fig. I. Upon the edge of the brass plate is drawn

Fig. I.



an arc of a circle concentric with the eyepiece, and this arc is then subdivided into degrees, and any fractional parts which may be required.[1]

By experimenting with a stage micrometer, we next endeavour to ascertain how far the pointer must be moved, in order that the crossed thread shall traverse a space in the field corresponding to $\frac{1}{100}$th of a millimetre. By simply manipulating on the stage of the instrument,

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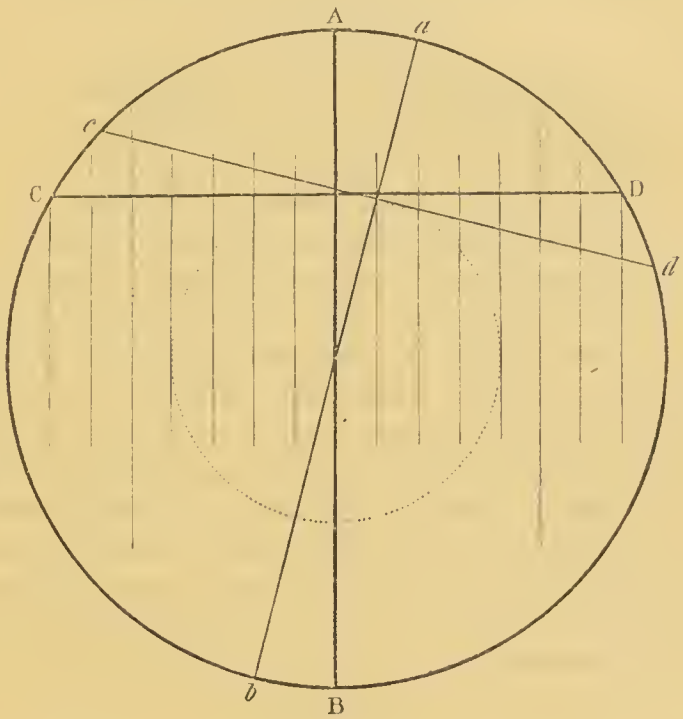
[1] This mode of division is preferable to a less exact method of constructing the scale, recommended by Welcker. The former involves, it is true, a little calculation in making measurements, but this disadvantage is more than compensated by the superior accuracy of the results obtained.

the stage micrometer can easily be put into the position shown in Fig. II., the long line A B accurately coinciding with a line of the

Fig. II.



micrometric scale. The eyepiece is then cautiously rotated, till the cross in the field, passing along the imaginary dotted circle in Fig. II., seems to touch the next line of the stage-scale, the long line now assuming the position *a b*. The arc traversed by the pointer during this rotation is then read off,—we shall suppose it an arc of 8^0. The *sine* of the corresponding arc of the dotted circle will, of course, indicate exactly $\frac{1}{100}$th of a millimetre; and from this simple foundation any measurement—*i. e.*, the length of the chord of any given arc in that circle—may be calculated; for the chord of any arc being equal to twice the sine of half that arc, the value of the chord of 8^0 is found as follows :—

Proportion.

As sin. 8° : ·01 Millimetre : : 2 sin. 4° : chord 8°

Calculation.

Log. 2 sine 4°	=	9·1446145
Log. ·01 Millim.	=	$\bar{2}$·0000000
		7·1446145
Subtract Log. sine 8°	=	9·1435553
Chord 8° = Num. ·0100244 Millim.	=	$\bar{2}$·0010592

The same result may be obtained from the following proportion, both sine and chord being supposed drawn :—

Proportion.

Rad. : ·01 Millim. : : secant 4° : chord required.

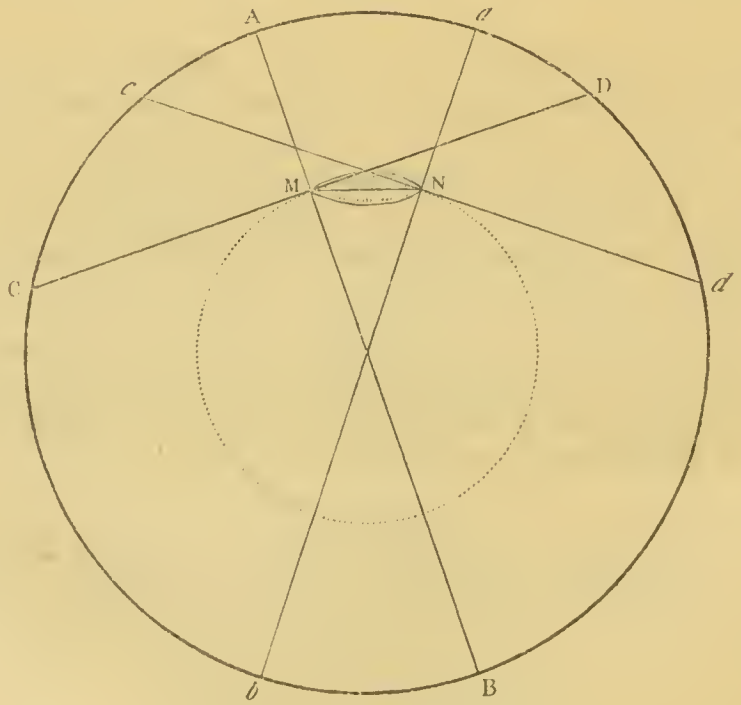
Calculation.

Log. secant 4°	=	10·0010592
Log. ·01 Millim.	=	$\bar{2}$·0000000
Subtract Log. Radius	=	10·0000000
Chord 8° = Num. ·0100244 Millim.	=	$\bar{2}$·0010592

The equivalent number ·0100244 is the required value of the chord of 8^0 in fractional parts of a millimetre. This or some other chord having been carefully determined by the instrument-maker, or observer, it should be noted down, as essential for the exactitude of all measurements to be afterwards made. It will save trouble if its logarithm be also recorded.

Mode of using the Instrument.—Suppose we wish to measure the long axis of an object, such as M N in Fig. III., we so arrange it on the stage that the cross in the field will, when the eyepiece is rotated, touch first the extremity M, and then the other extremity N. The arc A *a*, traversed by the pointer, is read off from

Fig. III.



the brass scale. The chord of the corresponding arc of the imaginary dotted circle is the measure of M N. Its length may be calculated with the greatest ease by the help of the ordinary lo-

garithmic tables of sines. In comparing chords, we use the sines of half their including arcs, as in the example which is appended :—

EXAMPLE.—See Fig. III.

The arc A *a* is found = 38°
Required the length of M N.

Proportion.

Sine 4° : ·0100244 Millim. : : Sine 19° : M N.

Calculation.

Log. ·0100244 Millim.	=	$\bar{2}$·0010592
Log. sine 19°	=	9·5126419
		7·5137011
Subtract Log. sine 4°	=	8·8435845
M N. = Num. ·0467861 Millim.	=	$\bar{2}$·6701166

In like manner the length of any other chords of the dotted circle may be easily determined;[1] and a table—if required—drawn up, from which the measure corresponding to each degree of the scale can, by mere inspection, be at once ascertained.

When the eyepiece rotates smoothly in the tube of the microscope, and a magnifying power of 500 or 600 diameters is used, measurements may be made with such an instrument with the utmost nicety. Welcker recommends that the top of the tube of the microscope should terminate in a hollow cone, into which is received a conical collar, supporting the pointer, and slipt on immediately beneath the milled rim of the eyepiece. The errors of manipulation should hardly exceed $\frac{1}{40,000}$th of an inch,—a degree of exactitude scarcely attainable by the cobweb screw-micrometer. An instrument constructed for me, by Mr James Bryson of Edinburgh, on the plan above described, has been tried against a finely-finished screw-micrometer, and found to perform with very great accuracy.

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[1] It is, however, unnecessary to carry these calculations beyond the fourth or fifth decimal place; for the unavoidable errors of observation render the apparent accuracy of the sixth and seventh places quite illusory.

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